VALIDATION OF A SIMULATION MODEL FOR DEER AND ELK FORAGE IN MIXED CONIFER VEGETATION

Peter F. Ffolliott

VALIDATION OF A SIMULATION MODEL FOR DEER AND ELK FORAGE IN MIXED CONIFER VEGETATION

Research Project Completion Report

Cooperative Agreement 16-385-CA

Submitted to: David R. Patton
Rocky Mountain Forest and Range Exp. Sta.
Forest Hydrology Lab., ASU Campus
Tempe, Arizona 85281

Submitted by: Peter F. Ffolliott
School of Renewable Natural Resources
College of Agriculture
University of Arizona
Tucson, Arizona 85721

August 27, 1975

SUMMARY

This narrative statement briefly summarizes our findings concerning the feasibility of employing an existing model (re: Giles, Robert H., and Nathan Snyder. 1970. Simulation techniques in wildlife management. In: Modelling and Systems Analysis in Range Science. Donald A. Jameson (ed.), Range Science Department, Science Series No. 5, Colorado State University, pp. 23-49.), as described in study plan entitled, "Validation of a Simulation Model for Deer and Elk Forage in Mixed Conifer Vegetation," approved July 31, 1974.

The program listing obtained for the above-mentioned model, obtained from the USDA Forest Service, Missula, Montana, was not accompanied by a users manual, and we have since discovered that no manual is available. By itself, the program listing is inadequately commented to readily facilitate its use (re: Appendix A).

Perhaps more important than programming difficulties, we now feel that the basic intent and objective of the above-mentioned model is not suitable, even through direct modification, for satisfying the objective of predicting deer and elk forage production and composition, and persistence through successional changes following management re-direction in mixee conifer vegetation. The original model was designed for big game winter range (primarily seral brush communities in the northern Rocky Mountains). Our interest centers on forested summer range. Furthermore, the original model was developed to provide alternative information sets as to size and type of vegetation management re-direction needed to most efficiently produce successional stages that would lead to increases (or maintenance) of big game populations at predetermined levels. We desire knowledge as to changes in deer and elk habitat potentials resulting from vegetation manipulations designed to obtain

specified multiple use benefits. And finally, use of the original model requires considerable basic successional information relating forage production to successional ages of specified management units. Information on successional patterns for mixed conifer vegetation in Arizona is presently incomplete.

Therefore, it is our conclusion that the above-mentioned model cannot be used to satisfy the needs as described in the study plan. Our specific suggestions regarding other modelling approaches have been summarized and were presented in a paper presented at a workshop on modelling of deer-forage-timber relationships held at Nacogdoches, Texas (re: Appendix B). Currently, a study designed to implement the suggestions outlined in this paper is underway (re: Cooperative Agreement 16-536-CA).

Attachments: Appendix A. Program Listing
Appendix B. Paper presented at workshop on modelling of deer-forage-timber relationships held at Nacogdoches, Texas.

APPENDIX A

```
      PROGRAM FORAGE
C
C     WRITTEN FOR R-1, USFS BY B. C. CLINKINGBEARD, 1970.
C    MAJOR REVISION JULY, 1973.
C
C    ******************************
C     CODE 1 IN 78 FOR ≠LIMITED≠ RUN.
C    ************************
      COMMON IXX(132),NELEG
      COMMON/DATA/ IFOR,IDIS,KSTA,MUNIT,ID(7),KYR1,J3,OBJ1,OBJ2,DEER,
     * LYEAR,NOTAB1,NAMEF(8),NAMED(8),NACRES(100),COEF(80),TACR,NOEX,
     * JYR(26),NUM3,JEXAR(100),NPAGE,DAY,IWACRES(100)
      NELEG = 0
      CALL CURVE (KUT)
      IF (KUT .EQ. 999) GO TO 10
      CALL BRINGIN
      IF (NOTAB1 .EQ. 0) CALL TAB1
IMproper logicAL IF      IF (J3) CALL TAB3
   "     "    "          IF (LYEAR .AND. NELEG) CALL TAB4
   10 PRINT 100, ID
  100 FORMAT (≠-END OF HABITAT SIMULATION FOR ≠,7A4,≠ MANAGEMENT UNIT.≠)
      RETURN
      END
```

```
      SUBROUTINE FOXHEAD (NN)
      COMMON/DATA/ IFOR,IDIS,KSTA,MUNIT,ID(7),KRY1,J3,OBJ(3),LYEAR,NO1,
     * NAMEF(8),NAMED(8),ACRES(100),COEF(80),TACR,NOE(128),NPAGE,DAY
      COMMON/DATA/ IWACRES(100)
      COMMON LINE,KOIV
      INTEGER ACRES
      LINE = 0
      NPAGE = NPAGE + 1
      PRINT 100, DAY,NPAGE
      PRINT 200, NAMEF,NAMED,MUNIT,ID
      IF (NN) GO TO 10
      PRINT 300
      PRINT 400
      PRINT 1100
      DO 5 I=1,99
      IF (ACRES(I) .EQ. 0) GO TO 5
      PRINT 500, I,ACRES(I),IWACRES(I)
      LINE = LINE + 1
    5 CONTINUE
      PRINT 600, TACR,IWACRES(100)
      LINE = LINE + 5
   10 PRINT 700
      PRINT 800
      PRINT 900
      PRINT 1000
      PRINT 1100
      LINE = LINE + 7
      KOIV = 1
      RETURN
  100 FORMAT (1H1,A8,35X,≠TABLE 4A - UNITS TREATED IN ACHIEVING GOAL≠,
     * 38X,≠PAGE≠,I3)                                          1X
  200 FORMAT (≠0FOREST ≠,8A4,10X,≠DISTRICT ≠,8A4,8X,I3,X,7A4)
  300 FORMAT (1H0,39X,≠TOTAL ACRES IN MANAGEMENT UNIT BY CURVE TYPE≠)
  400 FORMAT (1H0,47X,≠CURVE TYPE≠,8X,≠ALL AREAS    WINTER RANGE≠)     ≠ = *
  500 FORMAT (50X,I4,7X,2I14)
  600 FORMAT (1H0,59X,≠TOTAL≠,F10,I14)    Maybe 10.1
  700 FORMAT (1H0,39X,≠HABITAT UNITS TO BE TREATED IN NEXT 50 YEARS≠)
  800 FORMAT (1H0,36X,≠BEFORE TREATMENT≠,27X,≠AFTER TREATMENT≠)
  900 FORMAT (≠  TREATMENT≠,5X,≠CURVE≠,5X,≠HABITAT≠,8X,≠FORAGE≠,9X,
     * ≠RECOMMENDED≠,12X,≠CURVE≠,7X,≠FORAGE≠,20X,≠SPECIAL≠)
 1000 FORMAT (≠     YEAR≠,8X,≠TYPE≠,8X,≠UNIT≠,5X,≠POUNDS PER ACRE≠,5X,
     * ≠TREATMENT≠,13X,≠TYPE    POUNDS PER ACRE≠,5X,≠ACRES≠,7X,≠UNIT≠)
 1100 FORMAT (1H )
      END
```

```
      SUBROUTINE KWAL (JY1,JY2)
      COMMON KT,KU
      JY1 = JY2 = 0
      IF (KT .EQ. 9 .OR. KT .EQ. 10 .OR. KT .EQ. 57) GO TO 15
      IF (KT .EQ. 0) GO TO 15
      IF (MOD(KT,2)) GO TO 5
      IF (KT - 2 .AND. KT - 8 .AND. KT - 10) 12,15
    5 IF (KT .LT. 11 .AND. KT .GT. 1 .OR. KT .GT. 45) 10,15
   10 IF (KT .EQ. 49 .OR. KT .EQ. 53 .OR. KT .EQ. 57) 15,12
   12 JY1 = 1
   15 IF (KU .LT. 1 .OR. KU .GT. 60) JY2 = 2
      RETURN
      END
```

```
      FUNCTION NEXCODE (KUR,AGE,TRT,EXP,AC,CNO)
      INTEGER AGE,TRT,EXP,CNO
      DIMENSION MTR(23),NKO(23),KOBS(23)
      DATA (MTR = 2,8,1,9,10,11,15,17,27,29,35,37,43,45,13,19,21,23,25,
     * 31,33,39,41),
     * (KOBS = 4,4,4(2),6,10,4(8),6,10,2,10,10,2,10,6,10,6,10),
     * (NKO = 0,7,0,2,2,1,5,6,8,3(57),5,6,7,8,8,7,8,6,8,6,8)
C  DETERMINES CURVE CODE AFTER TREATMENT.
C  EXP = 1,2, OR 8 FOR NORTH SLOPE. KEX = 0 FOR SOUTH, 2 FOR NORTH.
C  CNO = 1 IF PRESENT, 2 IF NOT.
      IF (TRT .EQ. 49 .OR. TRT .EQ. 57) GO TO 45
      KEX = 0
      IF (EXP .LT. 3 .OR. EXP .GT. 7) KEX = 2
      DO 5 I=1,23
      IF (TRT - MTR(I)) 5,10
    5 CONTINUE
   10 IF (KUR .GT. 10) GO TO 40
      IF (TRT .LT. 3) GO TO (15,35),  TRT
      NEXCODE = NKO(I)
      IF (I .EQ. 3) NEXCODE = 4 - KEX
      RETURN
C  TRTMNT CODE 1.
   15 NEXCODE = 1
      GO TO (25,20,30,20,20,20,25,20), KUR
   20 RETURN
C  CURVES 1 AND 7.
   25 IF (AGE .GT. 5 .AND. AGE .LT. 30) NEXCODE = 2
      RETURN
C  CURVE 3.
   30 IF (AGE .LT. 12 .OR. AGE .GT. 60) RETURN
      NEXCODE = 4
      IF (AGE .GT. 30) NEXCODE = 2
      RETURN
C  TRTMNT CODE 2.
   35 NEXCODE = 4
      IF (KUR .EQ. 3 .AND. AGE .GT. 5 .AND. AGE .LT. 61) RETURN
      NEXCODE = 1
      IF (KEX .EQ. 0) NEXCODE = 3
      RETURN
C  ZONE 2 CODES 3X,4X,5X,6X.
   40 KLAS = (KUR -1) / 10
      NEXCODE = KLAS * 10 + KOBS(I)
      IF (I .LT. 15 .AND. I-2) NEXCODE = NEXCODE - CNO
      IF (I .LT. 3) NEXCODE = NEXCODE - KEX
      RETURN
   45 NEXCODE = KUR
      RETURN
      END
```

```
      SUBROUTINE TAB3
      COMMON/DATA/ IFOR,IDIS,KSTA,MUNIT,ID(7),KYR1,J3,OBJ1,OBJ2,DEER,
     * LYEAR,NO1,NAMEF(8),NAMED(8),NACRES(100),COEF(80),TACR,NOEX,
     * JYR(26),N3,JEX(100),NPAGE,DAY
      COMMON/DATA/ IWACRES(100)
      COMMON FEQ(26),AN(26)
      DIMENSION CMAX(100),CMIN(100)
      DATA (CMAX = 493.26,499.07,467.97,514.10,447.92,194.85,246.71,
     * 104.93,550.,450.,10(0.),200.,400.,600.,800.,1000.,5(0.),
     1 500.,250.,500.,250.,425.,210.,15.,10.,300.,100.,425.,210.,
     2 425.,210.,350.,175.,30.,15.,225.,75.,350.,175.,350.,175.,
     3 300.,225.,50.,25.,180.,65.,40(0.))
      DATA (CMIN = 8(50.),421.43,407.14,10(0.),200.,400.,600.,800.,1000.
     *, 5(0.),15.,10.,15.,10.,30.,15.,15.,10.,15.,15.,30.,15.,30.,15.,
     1 50.,25.,30.,15.,30.,30.,50.,25.,50.,25.,15.,30.,50.,25.,50.,50.
     2, 40(0.))
      EQMAX = EQMIN = 0.
      MT = 1          $REWIND MT
      IF (N3) 1,40
    1 DO 5 I=1,26
    5 FEQ(I) = AN(I) = 0.
   10 READ (MT,100) A,PCT,KYRO,Q,KU
  100 FORMAT (15X,F5,2X,F3.2,I3,F3.2,I2)          maybe F5.1 or F5.2
      GO TO (25,15), EOFCKF (MT)
   15 DO 20 I=1,N3
      NYR = JYR(I) - KYRO
      IF (JYR(I) .LT. 500) NYR = NYR + 1000
      EQ = Q * A *  CMAG(NYR,KU)
      FEQ(I) = FEQ(I) + EQ
      AN(I) = AN(I) + EQ * PCT / 3.
      IF (I-1) GO TO 20
      EU = Q * A * CMAX(KU) * PCT
      EL = Q * A * CMIN(KU) * PCT
      EQMAX = EQMAX + EU
      EQMIN = EQMIN + EL
   20 CONTINUE
      GO TO 10
   25 REWIND MT
      DO 35 I=1,N3
      IF (MOD(I,20) - 1) GO TO 30
      NPAGE = NPAGE + 1
      PRINT 1000, DAY,NPAGE
      PRINT 2000, NAMEF,NAMED,MUNIT,ID
      PRINT 3000, TACR,IWACRES(100)
      PRINT 4000
      PRINT 5000
   30 FEQ(I) = FEQ(I)/TACR
      JYR(I) = JYR(I) + 1000
   35 PRINT 200, JYR(I),FEQ(I),AN(I)
      ANMAX = EQMAX / 3.
      ANMIN = EQMIN / 3.
      EQMAX = EQMAX /IWACRES(100)
      EQMIN = EQMIN /IWACRES(100)
      PRINT 6000
      PRINT 7000, EQMAX,EQMIN,ANMAX,ANMIN
      RETURN
   40 N3 = 11
```

```
      DECODE (8,300,DAY) IY
  300 FORMAT (6X,I2)
      IY = 840 + IY
      DO 45 I=1,11
   45 JYR(I) = IY + I*10
      PRINT 400
  400 FORMAT (≠1YEARS MISSING FOR TABLE 3 - PROGRAM HAS SUPPLIED ONES US
     *ED≠)
      GO TO 1
  200 FORMAT (1H0,29X,I4,26X,F9.1,29X,F8)
 1000 FORMAT (1H1,A8,15X,≠TABLE 3 - ESTIMATED FORAGE PRODUCED AND ANIMAL
     *-UNIT DAYS SUPPORTED IN DESIGNATED YEARS≠,14X,≠PAGE≠,I3)
 2000 FORMAT (≠0FOREST ≠,8A4,10X,≠DISTRICT≠,X,8A4,8X,I3,X,7A4)      1X . . . . 1X
 3000 FORMAT (1H0,43X,≠TOTAL UNIT ACREAGE≠,F6,10X,≠WINTER RANGE≠,I6)
 4000 FORMAT (1H0,56X,≠FORAGE EQUIVALENTS≠,15X,≠ANIMAL-UNIT DAYS SUPPORT
     *ED≠)
 5000 FORMAT (30X,≠YEAR≠,25X,≠POUNDS PER ACRE≠,21X,≠ON WINTER RANGE≠)
 6000 FORMAT (1H-,10X,≠WINTER RANGE POTENTIALS≠,26X,≠MAX≠,6X,≠MIN≠,
     * 21X,≠MAX≠,14X,≠MIN≠)
 7000 FORMAT (1H0,55X,2F9.1,8X,2F17)
      END
```

```
      SUBROUTINE BRINGIN
      COMMON/DATA/ IFOR,IDIS,KSTA,MUNIT,ID(7),KYR1,J3,OBJ1,OBJ2,DEER,
     * LYEAR,NOTAB1,NAMEF(8),NAMED(8),ACRES(100), COEF(80),TACR,NOEX,
     * JYR(26),N3,JEXAR(2,50),NPAGE,DAY
      COMMON/DATA/IWACRES(100)
      COMMON KYRO,AC,IUN,Q,KUR,KTR,KEX,CNO,UN(50),KK(20),MTR,NYOR
      DIMENSION JSPEC(100),LIMUNITS(500)
      DIMENSION K37(2)                   Change variable name (too many characters)
      INTEGER CNO,ACRES
      EQUIVALENCE (JSPEC,JEXAR), (K37,KK(10))
      CHARACTER K37
      TACR = 0.
      L1 = -21      $NH =NOEX = 0
      N3 = 0
      DO 1 I=1,50
      IWACRES(I) = IWACRES(I+50) = 0
      ACPES(I) = ACRES(I+50) = 0
    1 UN(I) = 0.
      MALL = 1      $REWIND MALL
      MTR  = 2      $REWIND MTR
      REWIND 54     $REWIND 55
    5 READ 100, KK
  100 FORMAT (20A4)
      GO TO (95,10), EOFCKF (60)
   10 DECODE (2,2000,KK) KO
 2000 FORMAT (I2)
      GO TO (15,40,20,35), KO
C  HEADER
   15 DECODE (79,3000,KK) IFOR,IDIS,KSTA,MUNIT,ID,KYR1,KYR2,J3,OBJ1,OBJ2
     *, DEER,LYEAR,LIMITED,NOTAB1
 3000 FORMAT (2X,3I2,I3,7A4,6X,2I4,I1,2F4.2,F7,I4,4X,2I1)
      NYOR = KYR1 - 1000
      IF (LIMITED .EQ. 0) GO TO 5
C     NON-ZERO LIMITED - ENUMERATE AND LIST UNITS.
      LIM = -19
 3100 LIM = LIM + 20
      READ 3200, KK
 3200 FORMAT (20I4)
      GO TO (3500,3300), EOFCKF(60)
 3300 DO 3400 I=1,20
      K = LIM + I - 1
 3400 LIMUNITS(K) = KK(I)
      GO TO 3100
 3500 LIM = LIM + 19
      GO TO 5
C  TABLE 3 YEARS.
   20 DECODE (80,4000,KK) JYR
 4000 FORMAT (2X,26I3)
      J3 = 1
      DO 25 I=1,26
      IF (JYR(I)) 25,30
   25 CONTINUE
      N3 = 26
      GO TO 5
   30 N3 = I - 1
      GO TO 5
C  SPECIAL UNITS.
```

```
   35 L1 = L1 + 22
      L2 = MINO (L1 + 21,100)
      DECODE (80,5000,KK) (JSPEC(I),I=L1,L2)
 5000 FORMAT (3X,11(I4,I3))
      GO TO 5
C  HABITAT DATA.
   40 IF (LIMITED .EQ. 0) GO TO 4200
      DECODE (7,7000,KK(3)) IUN
      DO 4100 I=1,LIM
      IF (IUN - LIMUNITS(I)) 4100,4200
 4100 CONTINUE                 VARIABLE name too many characters
      GO TO 5
 4200 IF (NH) GO TO 55
C  COUNT SPECIAL UNITS WHEN FIRST 02 IS READ.
      CALL TLU (IFOR,NAMEF)
      CALL RDLU (IFOR,IDIS,NAMED)
      NPAGE = 0
      DAY = DATE (DAY)
      NH = 1
      IF (L1 .LT. 0) GO TO 55
      DO 45 I=2,L2,2
      IF (JSPEC(I)) 45,50
   45 CONTINUE
      NOEX = L2/2
      GO TO 55
   50 NOEX = (I-2) / 2
   55 WRITE (MALL,6000) (KK(I),I=1,9),K37
 6000 FORMAT (9A4,2A1)
      DECODE (30,7000,KK(3)) IUN,AC,PCT,KYRO,Q,KUR,KTR,KEX,CNO
 7000 FORMAT (3X,I4,F5,2X,F3.2,I3,F3.2,3I2,I1)
      MPCT = PCT * 100.
      ACRES(KUR) = ACRES(KUR) + AC
      IWACRES(KUR) = IWACRES(KUR) + AC * PCT
      IWACRES(100) = IWACRES(100) + AC * PCT
      TACR = TACR + AC
      IF (LYEAR .EQ. 0) GO TO 5
      NN = KYR1 - 1000 - KYRO
      DO 60 I=1,50
      NN = NN + 1
      PROD = CMAG(NN,KUR) * AC * Q/3. * PCT
   60 UN(I) = UN(I) + PROD
      IF (NOEX .EQ. 0) GO TO 75
      DO 65 I=1,NOEX
      IF (IUN - JEXAR(1,I)) 65,70
   65 CONTINUE
      GO TO 75
   70 WRITE (55) IUN,JEXAR(2,I),KYRO,KUR,AC,Q,KTR,KEX,CNO,PCT
      GO TO 5
C  CHECK FOR TREATABILITY.
   75 IF (KUR .LE. 10 .OR. KUR .GT. 30) CALL ELEG(MPCT)
      GO TO 5
C  END OF INPUT.
   95 ENDFILE MALL          $REWIND MALL
      ENDFILE MTR           $REWIND MTR
      ENDFILE 55            $REWIND 55
      WRITE (54) (UN(I),I=1,50)
      ENDFILE 54       $REWIND 54
      RETURN
      END
```

```
      SUBROUTINE ELEG(MPCT)
      COMMON KYRO,AC,IUN,Q,KUR,KTR,KEX,CNO,UN(50),KK(20),MT,KYR1,NELEG
      DIMENSION MIN(10),K78(6)
      DATA (K78 = 37,38,47,48,57,58)
      INTEGER CNO
      DATA (MIN = 20,8,34,20,20,12,32,12,40,40)
C  DETERMINES WHEN UNITS ARE ELEGIBLE FOR TREATMENT.
      IF (KTR .EQ. 0) RETURN
      DO 1 I=1,6
      IF (KUR .EQ. K78(I)) RETURN
    1 CONTINUE
      IF (KTR .LT. 3 .OR. KTR .GT. 7 .AND. KTR .LT. 11) GO TO 4
      DO 3 I=11,45,2
      IF (KTR - I) 3,4
    3 CONTINUE
      RETURN
    4 IAG = KYRO
      KOM = 30
      IF (KUR .LT. 11) KOM = MIN(KUR)
      IAG = IAG + KOM
      IAG = MAX0 (IAG,KYR1+1)
   10 IF(IAG .GT. KYR1 + 50) RETURN
      IF (CMAG(IAG-KYRO,KUR) .GT. 100. .AND. KUR .GT. 10) GO TO 15
      IFR = IAG + 1000
      M = Q * 100.
      IF (KYRO .GT. 1000) KYRO = KYRO - 1000
      WRITE (MT,100) IFR,KYRO,AC,IUN,M,KUR,KTR,KEX,CNO,MPCT
  100 FORMAT (I4,I3,F5,I4,I3,3I2,I1,I3)
      NELEG = NELEG + 1
      RETURN
   15 IAG = IAG + 1
      GO TO 10
      END
```

```
      SUBROUTINE MYSORT (IX)
      PRINT 30
      MT = 4
      REWIND MT
      IF (IX) GO TO 20
      WRITE (MT,11)
      WRITE (MT,12)
      WRITE (MT,10)
      GO TO 25
   20 WRITE (MT,21)
      WRITE (MT,22)
      WRITE (MT,13)
   25 WRITE (MT,24)
      REWIND MT
      CALL STINP (MT)
      CALL SORT
      CALL STINPCR
      RETURN
   11 FORMAT (≠01125510R 010304  ≠,24X,≠1100070001110004OO13≠,18(1H ))
   12 FORMAT (≠1ASI00290029F≠,7X,≠CM02     X≠,51(1H ))
   13 FORMAT (≠1B 000260026F≠,7X,≠CM01     X≠,51(1H ))
   10 FORMAT (≠1B 000290029F≠,7X,≠CM01     X≠,51(1H ))
   21 FORMAT (≠01125510R 010204  ≠,24X,≠1100080001≠,28(1H ))
   22 FORMAT (≠1ASI00260026F≠,7X,≠CM03     X≠,51(1H ))
   24 FORMAT (8H9ENDSORT,72(1H ))
   30 FORMAT (1H1)
      END
```

```
      SUBROUTINE TAB4
      COMMON/DATA/ IFOR,IDIS,KSTA,MUNIT,ID(7),KYR1,J3,OBJ1,OBJ2,NDEER,
     * LYEAR,NOTAB1,NAMEF(8),NAMED(8),NACRES(2,50),COEF(80),TACRES,NOEX,
     * JYR(26),NUM3,JEXAR(50,2),NPAGE,DAY
      COMMON/DATA/ IWACRES(100)
      REAL NDEER
      COMMON UN(50),FIN(50),WORK(50),TAC(50)
      INTEGER CNO
C  UN - YEARLY PRE-TRT PROD.  FIN - PROD GOAL BY YEAR.
C  WORK - WORKING ARRAY OF CURRENT PROD, WILL CONTAIN POST-TRT PROD AT END.
C  TAC - ACREAGE TRTD BY YEAR. EACH ENTRY MUST BE NO LARGER THAN
C        1/10 OF TOTAL ACREAGE.
      CALL MYSORT(0)
      NOYES = 0
      REWIND 54
      REWIND 55
      MOUT = 3      $REWIND MOUT
      MT = 1        $REWIND MT
      IPH = 1
C  IPH = 1 FOR SPEC UNITS, 2 FOR OTHERS.
C  NOYES = 1 IF GOAL UNOBTAINABLE.
      READ (54) (UN(I),I=1,50)
      DO 5 I=1,50
      WORK(I) = UN(I)
    5 TAC(I) = FIN(I) = 0.
C   REFORMULATE GOAL.  IX IS INDEX FOR LYEAR (GOAL YEAR).
      IX = LYEAR - KYR1
      IF (OBJ2) GO TO 15
      IF (OBJ1) NDEER = (1. + OBJ1) * UN(IX)
      DO 10 I=IX,50
   10 FIN(I) = NDEER
      GO TO 30
C  RAISE CURRENT PRODUCTION BY FIXED PCTG UNITL LYEAR.
   15 JX = IX + 1
      DO 20 I=1,JX
   20 FIN(I) = UN(1) * (1. + OBJ2) ** (I-1)
      DO 25 I=JX,50
   25 FIN(I) = FIN(JX)
      NDEER = FIN(JX)
   30 IF (NOEX .EQ. 0) GO TO 50
C  SPECIAL UNITS (FO 55).
   35 READ (55) IUN,KYRT,KYRO,KUR,AC,Q,KTR,KEX,CNO,PCT
      GO TO (50,40), EOFCKF (55)
   40 IF (KYRT .LT.  500) KYRT = KYRT + 1000
      KSPEC = 1H*
      JX = KYRT - KYR1 + 1000
   43 DO 45 I=JX,50
C  UNTRTD INDEX.
      NN = KYR1 + I - KYRO - 1000
C  TRTD INDEX
      JJ = I - JX
      IF (JJ) GO TO 45
      NEW = NEXCODE (KUR,NN,KTR,KEX,AC,CNO)
      MAG = CMAG(NN,KUR)
      MAGA = CMAG(0,NEW)
   45 WORK(I) = WORK(I) + (CMAG(JJ,NEW) - CMAG(NN,KUR)) * AC * Q /3.*PCT
C  DATA FOR 4A: REL YR TRTD, CURVE, UNITNO, LBS/A PRIOR TRT, TRT, ACRES.
```

```
      WRITE (MOUT,1000)  JX,KUR,IUN,MAG,KTR,NEW,MAGA,AC,KSPEC
 1000 FORMAT (2I2,2I4,2I2,I4,F5,A1)
C  ACCUM ACRES TREATED.
      TAC(JX) = TAC(JX) + AC
      GO TO (35,55), IPH
C  CONVENTIONAL UNITS. NOW IS TRT YR.
   50 KX = IX
      ACMAX = .1 * TACRES
      IPH = 2
C  SEE IF MORE UNITS MUST BE TREATED.
   55 DO 60 I=KX,50
      IF (WORK(I) .LT. FIN(I)) 65,60
   60 CONTINUE
      GO TO 90
?  65 READ (MT,2000) KYRT,KYRO,AC,IUN,Q,KUR,KTR,KEX,CNO,MPCT
 2000 FORMAT (I4,I3,F5,I4,F3.2,3I2,I1,I3)
      GO TO (85,68), EOFCKF(MT)
?  68 NOW = MAX0(KYRT,MAXPOWER(I,KUR))
      PCT = MPCT * .01          Too many characters
      IF (KX .EQ. I) NOW = MAX0(KYRT,KYR1 + 1)
      KSPEC = 1H
      JX = NOW - KYR1
   70 ACYR = TAC(JX) + AC
      IF (ACYR .LT. ACMAX) GO TO 43
      JX = JX + 1
      GO TO 70
C  GOAL UNREACHABLE.
   85 NOYES = 1
   90 ENDFILE MOUT
      REWIND MOUT
      PRINT 400, DAY
      PRINT 500, NAMEF,NAMED,MUNIT,ID
      IF (OBJ2 .EQ. 0.) GO TO 92
      OBB = OBJ2 * 100.
      PRINT 650, OBB,LYEAR,NDEER
      GO TO 93
  650 FORMAT (1H0,16X,≠OBJECTIVE : INCREASE ANIMAL DAYS SUPPORTED BY≠,
     * F4,≠ PCT PER YEAR UNTIL≠,I5,≠ AND STABILIZE AT≠,F8)
   92 PRINT 600, NDEER,LYEAR
   93 IF (NOYES) PRINT 700
      PRINT 750
  750 FORMAT (43X,≠ANIMAL-UNIT DAYS SUPPORTED ON WINTER RANGE≠)
      PRINT 800
  400 FORMAT (1H1,39X,≠TABLE 4 - TREATED VS UNTREATED PRODUCTION≠,40X,
     * A8)                                                   1X
  500 FORMAT (≠0FOREST ≠,8A4,10X,≠DISTRICT ≠,8A4,I8,X,7A4)
  600 FORMAT (1H0,27X,≠OBJECTIVE : INCREASE ANIMAL DAYS SUPPORTED TO≠,
     * F8,≠ AND STABILIZE FROM≠,I5,≠ ON≠)
  700 FORMAT (52X,≠** GOAL CANNOT BE REACHED **≠)
  800 FORMAT (1H0,10X,≠YEAR≠,5X,≠BEFORE TREATMENTS≠,6X,≠AFTER TREATMENTS
     *≠,21X,≠YEAR≠,6X,≠BEFORE TREATMENTS≠,6X,≠AFTER TREATMENTS≠)
      NYR = KYR1
      DO 95 I = 1,25
      NYR = NYR + 1
      NY25 = NYR + 25
   95 PRINT 3000, NYR, UN(I),WORK(I),NY25,UN(I+25),WORK(I+25)
4 3000 FORMAT (1H0,10X,I4,9X,F8,14X,F8,26X,I4,10X,F8,14X,F8)
```

```
      SUBROUTINE TAB1
      COMMON/DATA/ IFOR,IDIS,KSTA,MUNIT,ID(7),KYR1,J3,OBJ1,OBJ2,DEER,
     * LYEAR,NOTAB1,NAMEF(8),NAMED(8),NACRES(100),COEF(80),TACR,NOEX,
     * JYR(26),NUM3,JEXAR(100),NPAGE,DAY
      COMMON/DATA/ IWACRES(100)
      DIMENSION KOON(2)
      COMMON KTR,KU,TOT(6),COUN(6)
   ?  DATA (KOON = 8HNO  YES )
   ?  INTEGER CNO
      LIN = 60
      MT = 1        $REWIND MT
      DO 1 I = 1,6
    1 TOT(I) = COUN(I) = 0.
      COUN(2) = 1.
    5 IF (LIN .LT. 24) GO TO 10
      NPAGE = NPAGE + 1
      PRINT 2000, DAY,KYR1,NPAGE
      PRINT 3000, NAMEF,NAMED,MUNIT,ID
      PRINT 4000
      PRINT 5000
      PRINT 6000
      LIN = 0
? ? 10 READ (MT,1000) NBR,COUN(1),LEV,PCT,KYRO,Q,KU,KTR,KEX,CNO
 1000 FORMAT (11X,I4,F5,I2,F3.2,I3,F3.2,3I2,I1)
      GO TO (40,15), EOFCKF (MT)
   15 CALL KWAL (J1,J2)
      KYRO = KYRO + 1000
      IF (J2) GO TO 20
      NYR = KYR1 - KYRO
      COUN(4) = CMAG(NYR,KU)
      COUN(5) = COUN(4) * Q
      COUN(6) = COUN(5) / 3.
      COUN(3) = COUN(6) * PCT * COUN(1)
      GO TO 30
   20 DO 25 I=3,6
   25 COUN(I) = 0.
   30 DO 35 I=1,3
      TOT(I) = TOT(I) + COUN(I)
   35 TOT(I+3) = TOT(I+3) + COUN(I+3) * COUN(1)
      PCT = PCT * 100.
      PRINT 200, NBR, COUN(1),LEV,PCT,KYRO,Q,KU,KTR,KEX,KOON(CNO+1),
     * (COUN(I),I=4,6),COUN(3)
  200 FORMAT (1H0,I4,F8,I6,F8,  I9,F9.2,I7,I9,I7,5X,A4, F9.1,F12.1,
     * F13.1,F15)
      LIN = LIN + 1
      IF (J1 + J2 .EQ. 0) GO TO 5
      IF (J1) PRINT 600
      IF (J2) PRINT 700
      LIN = LIN + 1
      GO TO 5
   40 DO 45 I=4,6
   45 TOT(I) = TOT(I) / TOT(1)
      PRINT 300
      PRINT 400, TOT(1),IWACRES(100),(TOT(I),I=4,6),TOT(3)
      PRINT 500, TOT(2)
      REWIND MT
      RETURN
```

```
  300 FORMAT (1H0,9X,≠TOTAL UNIT ACREAGE≠,/6X≠ALL AREAS≠,7X,
     * ≠WINTER RANGE≠,53X,≠WEIGHTED AVERAGES≠,15X,≠TOTAL≠)
  400 FORMAT (1H0,F12,12X,I7,49X,F5.1,F12.1,F13.1,F15)
  500 FORMAT (30X,F6,≠ HABITAT UNITS≠)
  600 FORMAT (12X,≠** ILLEGAL TREATMENT **≠)
  700 FORMAT (12X,≠** ILLEGAL CURVE CODE **≠)
 2000 FORMAT (1H1,A8,20X,≠TABLE 1 - INVENTORY OF FORAGE PRODUCTION AND A
     *NIMAL-UNIT DAYS SUPPORTED -≠,I5,20X,≠PAGE≠,I3)
 3000 FORMAT (≠0FOREST ≠,8A4,10X,≠DISTRICT ≠,8A4,9X,I3,X,7A4)
 4000 FORMAT (1H0,23X,≠  IN≠,76X,≠ESTIMATED ANIMAL-UNIT DAYS≠)
 5000 FORMAT (23X,≠WINTER≠,11X,≠QUALITY≠,11X,≠REC≠,22X,≠POUNDS PER ACRE≠
     * ,7X,≠PER ACRE≠,6X,≠PER YEAR≠)
 6000 FORMAT (≠ UNIT   ACRES   ELEV   RANGE   ORIGIN   FACTOR   CURVE≠,
     * 3X,≠TRTMNT   EXP≠,4X,≠CNO≠,4X,≠FORAGE≠,3X,≠EQUIVALENTS≠,4X,
     * ≠ALL AREAS    WINTER RANGE≠)
      END
```

```
          FINIS
      [[
      FUNCTION CMAG (IX,IN)
C  SOLVES SUCCESIONAL CURVE FOR GIVEN DISPLACEMENT
      DIMENSION L78(12)
      DATA (L78 = 37,38,47,48,57,58,15,10,30,15,50,25)
      COMMON/DATA/ IXXX(137),COEF(80)
      DIMENSION MAX(20),Z9A(80),Z9B(8),LOLO(504),LVAL(2,252),Z9(16)
      EQUIVALENCE (LOLO,LVAL),(Z9,Z9A),(Z9(9),Z9B)
      DATA (MAX = 40, 28, 67, 55, 24, 16, 40, 12, 12(0))
      DATA (Z9 = 2(400.),571.304348,457.608696,570.,440.,450.,420.,
     * 21.42857,7.142857,-3.043478,-1.0869565,-3.,-.5,0.,0.)
      DATA((LOLO(I),I=1,112) =
     *            0,15, 3,60, 6,170, 7,280, 10,430, 15,500, 20,470,          31
     * 24,400, 29,220, 35,80, 40,15, 40,15, 40,15, 40,15,                    31
     * 0,10, 3,30, 6,85, 7,140, 10,215, 15,250, 20,235, 24,200, 29,110,      32
     * 35,40, 40,10, 40,10, 40,10, 40,10,                                    32
     * 0,15, 3,60, 6,170, 7,280, 10,430, 15,500, 20,490, 30,380, 37,250,     33
     * 50,90, 60,30, 64,15, 64,15, 64,15,                                    33
     * 0,10, 3,30, 6,85, 7,140, 10,215, 15,250, 20,250, 30,190, 37,125,      34
     * 50,45, 60,15, 64,10, 64,10, 64,10)                                    34
      DATA ((LOLO(I),I=113,224) = 0,30, 3,60, 6,105, 10,200, 14,340,         41
     *  20,425, 27,380, 30,330, 35,200, 40,110, 46,50, 50,30, 50,30,         41
     *  50,30,      0,15, 3,30, 6,55, 10,100, 14,170, 20,210, 27,190,        42
     * 30,165, 35,100, 40,55, 46,25, 50,15, 50,15, 50,15,                    42
     * 0,30, 3,60, 6,105, 10,200, 14,340, 20,425, 30,405, 36,365,            43
     * 40,325, 50,185, 58,100, 69,40, 78,30, 78,30,                          43
     * 0,15, 3,30, 6,55, 10,100, 14,170, 20,210, 30,205, 36,185,             44
     * 40,165, 50,95, 58,50, 69,20, 78,15, 78,15)                            44
      DATA ((LOLO(I),I=225,336) = 0,50, 3,55, 6,70, 10,100, 14,150,          51
     * 20,275, 25,350, 29,340, 34,300, 40,205, 50,95, 55,65, 60,50,          51
     * 60,50,    0,25, 3,25, 6,35, 10,50, 14,75, 20,140, 25,175, 29,170,     52
     * 34,150, 40,105, 50,50, 55,35, 60,25, 60,25,                           52
     *  0,50, 3,55, 6,70, 10,100, 14,150, 20,275, 25,350, 40,340,            53
     * 47,330, 55,300, 64,240, 74,140, 81,80, 90,50,                         53
     *  0,25, 3,25, 6,35, 10,50, 14,75, 20,140, 25,175, 40,170, 47,165,      54
     * 55,150, 64,120, 74,70, 81,40, 90,25)                                  54
C   VALUES FOR 39,49,59.
      DATA ((LOLO(I),I=337,420) = 0,15, 3,60, 6,120, 7,155, 10,260,
     * 15,300, 17,285, 19,245, 20,210, 22,80, 25,15, 25,15, 25,15, 25,15
     *, 0,30, 3,60, 6,105, 10,175, 12,200, 20,225, 23,205, 25,175,
     * 27,125, 28,100, 30,60, 32,40, 35,30, 35,30, 0,50, 3,55, 6,60,
     * 10,75, 12,90, 15,110, 20,160, 25,180, 30,150, 33,110, 35,80,
     * 39,60, 42,55, 45,50)
C   VALUES FOR 40,50,60.
      DATA ((LOLO(I),I=421,504) = 0,15, 3,25, 6,35, 7,50, 10,30, 15,100,
     * 17,90, 19,75, 20,60, 22,35, 35,15, 35,15, 35,15, 35,15, 0,30,
     * 5,35, 7,40, 10,50, 12,60, 20,75, 22,70, 25,65, 26,60, 28,50,
     * 31,40, 33,35, 35,30, 35,30, 0,50, 6,55, 11,60, 15,65, 18,65,
     * 22,65, 25,65, 32,60, 38,55, 40,55, 45,50, 45,50, 45,50, 45,50)
      IF (IX .LT. 0) IX = 100                                            CMAG
      IF (IN .GT. 30) GO TO 20
      IF (IN .GT. 20) GO TO 5
      GO TO (2,10), IN-7
    2 IF (IX .AND. IX .LT. MAX(IN)) GO TO 4
      CMAG = 50.
      RETURN
```

```
    4 N = 4 * IN
      CMAG1= COEF(N-3)*IX**3 + COEF(N-2)*IX*IX + COEF(N-1)*IX + COEF(N)
      CMAG = AMAX1 (CMAG1,50.)
      RETURN
    5 CMAG = 200 + (IN-21) * 200
      RETURN
   10 N=4
      IF (IX .LT. 40) N = 3
      IF (IX .LT. 30) N = 2
      IF (IX .LT.  7) N = 1
      N = N*2+IN-10
      CMAG = Z9A(N) + Z9B(N)*IX
      RETURN
C     LOLO CURVES 31,32,33,34, 41,42,43,44, 51,52,53,54
C     LVAL (1,I) - YR      (2,I) - LBS
C     31:  1-14   32:  15-28  33:  29-42  34:  43-56
C     41: 35-70   42:  71-84  43:  85-98  44:  99-112
C     51:113-126 52: 127-140 53: 141-154 54: 155-168
   20 GO TO (60,22,22,22,22,22,22,45,45,60), MOD(IN,10) + 1
   22 ISTART = 1 + 56 * (IN/10 - 3)
      ISTART = ISTART + 14 * (MOD(IN,10) - 1)
   25 LAST = ISTART + 13
      DO 30 I = ISTART,LAST
      IF (LVAL(1,I) .GE. IX) 40,30
   30 CONTINUE
      CMAG = LVAL(2,LAST)
      RETURN
   40 YL = LVAL(1,I-1)        $YU = LVAL(1,I)
      VL = LVAL(2,I-1)        $VU = LVAL(2,I)
      CMAG = VL + (FLOAT(IX) - YL) / (YU-YL) * (VU-VL)
      RETURN
C      LOLO CURVES 37,38, 47,48, 57,58.
   45 DO 50 I=1,6
      IF (IN - L78(I)) 50,55
   50 CONTINUE
      CMAG = 0.
      RETURN
   55 CMAG = L78(I+6)
      RETURN
C     LOLO CURVES 39,49,59, + 40,50,60.
   60 ISTART = 169 + (IN/10 - 3) * 14
      IF (MOD(IN,10) .EQ. 0) ISTART = ISTART + 28
      GO TO 25
      END
```

```
      SUBROUTINE CURVE (KUT)
      COMMON/DATA/IXXX(137),COEF(80)
      READ 10, NCU
   10 FORMAT (I2)
      DO 1 I=1,NCU
      K1 = 4*I
      K0 = K1-3
      READ 3, IT,(COEF(K),K=K0,K1)
      IF (IT-I)2,1
    1 CONTINUE
      RETURN
    2 PRINT 4
      KUT = 999
      RETURN
?   3 FORMAT (I2,3X,4F10.9)
    4 FORMAT (26H0CURVE CODE SEQUENCE ERROR)
      END
```

```
      SUBROUTINE FOURA
      COMMON/DATA/ IXX(11),KYR1,JXX(417)
      COMMON LINE,KOIV,NDAT(9),KACRES,YACRES,GTO,NKUR
      EQUIVALENCE (KYRT,NDAT), (KURV,NDAT(2)), (AC,NDAT(8))
      INTEGER YEARB,YACRES,AC,GTO
      CALL MYSORT (1)
      MT = 1          $REWIND MT
      KOIV = INIT = GTO = 0
      CALL FOXHEAD (0)
    5 READ (MT,100) NDAT
  100 FORMAT (2I2,2I4,2I2,I4,I5,A1)
      IEOF = EOFCKF(MT)
      GO TO (22,10), IEOF
   10 GTO = GTO + AC
      KYRT = KYRT + KYR1
      IF (INIT) GO TO 20
      INIT = 1
   15 KURB = KURV
      YEARB = KYRT
?     CALL FOURLINE (1)
      NYR = NKUR = 1
      KACRES = YACRES = AC
      GO TO 5
   20 IF (YEARB .EQ. KYRT) 25,22
C  NEW YEAR.
   22 IF (NKUR .GT. 1) CALL FOURTOT (1)
      IF (NYR  .GT. 1) CALL FOURTOT (2)
      GO TO (35,15), IEOF
   25 IF (KURB .EQ. KURV) GO TO 30
C  NEW CURVE FOR YEAR.
      IF (NKUR .GT. 1) CALL FOURTOT (1)
      NKUR = KACRES = 0
      KURB = KURV
   30 NKUR = NKUR + 1
      NYR  = NYR + 1
      KV = KOIV
?     CALL FOURLINE (KV)
      KACRES = KACRES + AC
      YACRES = YACRES + AC
      GO TO 5
   35 CALL FOURTOT (3)
      RETURN
      END
```

```
      SUBROUTINE FOURLINE (IX)
      COMMON LINE,KOIV,NDAT(9),ITO(3),NKUR
      DIMENSION A(1),B(1),C(1),D(3)
      EQUIVALENCE (A,D),(B,D(2)),(C,D(3))
      DATA (A = 8H   CURVE), (B = 8H  YEARLY), (C = 8H   GRAND)
      IF (IX) GO TO 5
C  GENERAL DETAIL.
      IF (NKUR - 1) GO TO 1
      LINE = LINE + 1
      PRINT 400
  400 FORMAT (1H )
    1 LINE = LINE + 1
      PRINT 100, (NDAT(I),I=3,9)
  100 FORMAT (19X,I13,I14,I16,I19,I13,I15,9X,A1)
      IF (NKUR .EQ. 1) PRINT 150, NDAT(2)
  150 FORMAT (1H*,9X,I9)
      GO TO 15
C  FIRST DETAIL FOR YEAR OR PAGE.
    5 PRINT 200, NDAT
      KOIV = 0
  200 FORMAT (1H0,I7,I11,I13,I14,I16,I19,I13,I15,9X,A1)
      GO TO 10
      ENTRY FOURTOT
      PRINT 300, D(IX),ITO(IX)
  300 FORMAT (1H0,86X,A8,≠ TOTAL≠,I8)
   10 LINE = LINE + 2
   15 IF (LINE .GT. 48) CALL FOXHEAD(1)
      RETURN
      END
```

```
      FUNCTION MAXPOWER (I,KUR)
      COMMON/DATA/ IX(11),KYR1,JX(7),LYEAR,MX(409)
      DIMENSION MOST(10)
      DATA (MOST = 6(3),6,12,7)
      MM = KUR / 10 * 5
      IF (KUR .LT. 11) MM = MOST(KUR)
      INT = KYR1 + I - MM
      MAXPOWER = MAX0(KYR1 + 1,INT)
      RETURN
      END
```

APPENDIX B

Paper presented at Workshop on Modeling of Deer-Forage-Timber Relationships, Nacogdoches, Texas, December 3-5, 1974.

A SIMULATION MODEL FOR DEER AND ELK FORAGE IN ARIZONA MIXED CONIFER FORESTS

By

Peter F. Ffolliott and Ronald E. Thill

School of Renewable Natural Resources
University of Arizona

INTRODUCTION

In recent years, wildlife managers have shown an increasing interest in the use of simulation techniques employing computer models of ecological systems as a prediction tool, and as a means of generating and assessing alternative vegetation management practices in terms of wildlife resource response. For example, through the use of forage production data and, if appropriate, vegetation successional information, it may be possible to use simulation techniques to predict the level of forage production that is available as a wildlife food source after a vegetation management re-direction (thinning, clearing, etc.) has been imposed.

Availability of food has been shown to be a factor that may often limit deer and elk populations; it is also a factor that can be manipulated by vegetation management re-direction. Therefore, to strengthen a managers hand relative to deer and elk populations in Arizona mixed conifer forests, new simulation tehcniques are currently needed to predict and evaluate the effects of alternative vegetation management practices on deer and elk forage production, essentially by describing how forage production may be altered through successional changes that are attributed to the management practices.

Hopefully, a simulation technique may provide managers with a tool to

determine the level of forage production that will be available to deer and elk throughout a vegetation management rotation period. With this information, a manager may be able to plan the time, size, and type of vegetation management re-direction that is necessary to maintain a desired level of forage production for a given, and possibly specified, deer and elk carrying capacity.

OBJECTIVE

The Department of Watershed Management, University of Arizona, in cooperation with the Rocky Mountain Forest and Range Experiment Station, Tempe, Arizona, have jointly undertaken an exploratory study directed toward the development of a simulation technique to evaluate deer and elk forage in Arizona mixed conifer forests. Such a simulation technique could be used to augment management decision by describing the potential effects of alternative vegetation management prescriptions in terms of forage production, composition, and persistence through successional changes.

The primary objective of the current exploratory study is to assess, validate, and, if necessary, modify a simulation technique employing a computer model, originally developed to provide an evaluation basis for elk populations on a winter range in northern Idaho, to predict deer and elk forage production in Arizona mixed conifer forests. In essence, the simulation technique to be synthesized in this study is to be used to predict deer and elk forage production following proposed vegetation management re-directions to be imposed in these forests.

Mixed conifer forests occupy approximately 300,000 acres of moist, high elevation sites in north-central and east-central Arizona. These forests provide important summer range for deer, elk, and domestic livestock, despite

their typically dense overstories of various mixtures of Engelmann spruce, Douglas-fir, white fir, ponderosa pine, and quaking aspen.

This paper is essentially a progress report on the initial work that has been conducted relative to satisfying the study objective.

STUDY AREA

The study area, or validation site, that was selected to provide source data for the study is the South Fork of Thomas Creek, an experimental watershed located on the Apache-Sitgreaves National Forest in east-central Arizona. This experimental watershed, approximately 550 acres in size, is assumed to represent the vegetative, physiographic, and climatic conditions that are commonly associated with the mixed conifer forests in Arizona. Furthermore, this experimental watershed will be subjected to a vegetation management re-direction within the next year, allowing on-site assessments and validations to be made.

DESCRIPTION OF ORIGINAL SIMULATION TECHNIQUE

One of the few simulation techniques of the nature originally saught in the current study appeared to be the computer model described by Giles and Synder (1970) for application on the Clearwater winter elk range in northern Idaho. Since its initial development, this simulation technique has been, and is being, employed and refined by USDA Forest Service personnel in Region One for use in the seral brush communities in Idaho and Montana. Basically, it is being used to provide alternative information as to size and type of vegetation management re-direction needed to gradually increase (or at least maintain) deer and elk populations at a predetermined level on a yearly basis.

A brief description of the simulation technique described by Giles and Synder (1970) may provide background for the exploratory study discussed in this paper. The basic design of the simulation technique rests on the assumptions that (1) forage on winter ranges is the determining factor that governs deer and elk populations, (2) available forage is dependent upon the stage of plant succession, and (3) within a period of a few years, deer and elk populations will increase to a limit dictated by available forage. If these assumptions are valid, and if information is on hand to relate forage production to successional changes, it then may be possible to estimate the required acreage to be subjected to cutting, burning, or planting that is necessary to create seral brush communities that will supply the additional forage needed to increase deer and elk populations.

An inventory system has been developed by the USDA Forest Service to provide information required as inputs to the simulation technique developed by Giles and Snyder (1970). For each vegetation type within each management unit of interest, the following information is obtained: (1) area description and year of origin (such as the year the area was last cut, burned, or planted), (2) percent of the area in winter range, (3) elevation, (4) exposure, (5) recommended treatment (additional cutting, burning, or planting), if any, and (6) the quality factor for the forage being produced on the area. The quality factor is used in an attempt to standardize areas as to differences in preferred forage species, quality and availability, and other influences such as distance of forage from suitable game cover.

Perhaps the factor limiting the use of this simulation technique for most areas is the lack of data that relates forage production to the various successional patterns on a management unit. The approached used in Idaho and

Montana, at least initially, was to establish forage production levels indirectly from fecal pellet group survey data. Estimated weight of forage utilized was determined by assuming (1) a defication rate of 13 pellet groups per day for deer and elk, and (2) a mean daily forage consumption of 4.5 pounds (air-dry) for deer and 12 pounds (air-dry) for elk. Arbitrarily, total forage production was assumed to be twice the calculated amount of forage utilized. Conceivably, for areas where pellet group data are available for all or most areas of different successional stage, such an approach may seem suitable, so long as factors converting forage utilized to forage produced are known.

For each management unit, forage production is converted to forage equivalents by multipying forage production values by the appropriate quality factor. Then, forage equivalents, divided by the amount of forage needed to support an average of 100 pounds of animal, yields an estimate of available forage in terms of animal-unit-days which could be supported on the management unit. Potential animal-units available on winter range only is the product of (1) the percent of each management unit that is in winter range, (2) the number of acres, and (3) the animal-unit-days which could be supported on a per acre basis.

Since total available forage is normally higher than the amounts actually utilized, or which should be utilized in terms of proper use, subjective judgments are required in interpreting the resulting computer output of the simulation. Using the inventory data, appropriate forage production data, and appropriate management constraints, the computer generates various alternatives as to vegetation types and sizes that could be treated to most efficiently achieve a desired deer and elk population goal.

DIFFICULTIES IN USING THE ORIGINAL STIMULATION TECHNIQUE

Considerable modification and refinement have undoubtedly been made and incorporated into the computer program of the original simulation technique since it was described by Giles and Synder (1970). Unfortunately, the computer program as received from the USDA Forest Service was not accompanied with a users manual, and it was insufficiently commented to facilitate ready use.

Even if all existing programming difficulties could be resolved, additional factors appear to limit the usefulness of this computer program for satisfying the objectives of the current exploratory study. First, sufficient data to synthesize the required curves relating forage production to successional stage patterns for Arizona mixed conifer forests are presently incomplete. Secondly, the original simulation technique was primarily designed for use in seral brush communities representing winter ranges in Idaho and Montana; in the current study, interest is focused on forested summer ranges. Finally, the original simulation technique was essentially concerned with achieving specified big game population responses through vegetation manipulation; on the other hand, the objective of the current study is the prediction of deer and elk forage production, composition, and persistence through successional changes following various alternative vegetation management re-directions which may be imposed in Arizona mixed conifer forests.

OTHER APPROACHES TO DEVELOPMENT OF SIMULATION TECHNIQUE

Forage production is a function of numerous environmental factors, any combination of which could prove useful as an estimating basis. Thus, in addition to, or as an alternative to using successional information, multiple regression analyses could be used to identify combinations of factors most

significantly influencing forage production in Arizona mixed conifer forests.

The apparent effect of light penetration has received considerable attention, and many investigators have developed predicting equations that relate forage production to canopy cover or other expressions of forest density (Ffolliott and Clary 1972). Inherent in such approaches should be the realization that many environmental parameters vary concomitantly with changes in canopy cover or other expression of forest density, and its effect on light penetration.

Light penetration is but one of many factors that may influence forage production. In Wisconsin, for example, the effect of canopy cover on precipitation interception losses was considered more important than light penetration in determining forage production levels (Anderson _et al._ 1969).

Possible factors in addition to canopy cover or other expressions of forest density to be assessed for their usefulness in a deer and elk forage prediction model in Arizona mixed conifer forests may include (1) elevation, (2) exposure, (3) precipitation amount and distribution, and (4) numerous soil attributes. The depth of the forest floor might also warrant consideration. Forage production has been found to vary inversely with increasing depth of litter, duff, and humus in Arizona ponderosa pine forests (Clary _et al._ 1968), and similar findings have been reported elsewhere.

In an approach somewhat analoguous to using forest density as an inventory-prediction variable, a high degree of correlation has been found when forage production is related to annual forest growth in Arizona ponderosa pine forests (Ffolliott and Clary 1974). As previously mentioned, many empirical relationships have been developed to describe annual forage production in relation to forest density. However, while forage production is a measure of

annual yield, expressions of forest density (canopy cover, volume, number of trees, or basal area) describe a cumulative production situation at a point in time. This may be unfortunate, as a more sensitive basis for evaluating forage and forest interactions may be derived by quantifying yields on a common time scale. Such an approach requires knowledge of annual forest growth rates, but such information is often easily obtained from basic forest inventory data.

To identify factors that may be potentially useful for predicting forage production in lodgepole pine forests, investigators in Montana have employed multiple regression analyses to test over 30 environmental parameters (Basile and Jensen 1971). In addition to time since vegetation management re-direction (in this case, logging) and various expressions of topography and forest density, influences of the following variables were studied: (1) average tree height, (2) site index, and (3) soil characteristics such as bulk density, horizon thickness, pH, water holding capacity, percent sand, silt, and clay, total nitrogen, available potassium, and percent organic matter. Using various combinations of inventory-prediction variables, equations were developed for predicting forage production. Due to the relatively small tree height and low canopy cover on sites recently subjected to vegetation management re-direction, the effects of lodgepole pine forest density on various factors, including light penetration, could not be adequately assessed. Variables which proved most useful for forage prediction included successional stage and some of the soil characteristics.

In the current exploratory study, it is hoped that a suitable simulation technique for forage production can be keyed primarily to source data typically available from basic forest inventories in Arizona mixed conifer forests.

Initially, an attempt is being made to isolate those variables that relate most directly to deer and elk forage production. In this attempt, two categories of inventory-prediction variables are being recognized: (1) those variables which may be directly affected by vegetation management re-direction, such as forest density and annual forest growth rates, and (2) those variable not directly affected by vegetation management re-direction, including elevation, exposure, soil characteristics, and site index. Once sufficient descriptive data for each inventory-prediction variable are compiled, appropriate statistical analyses will be used to screen and identify those variables which singularly or in combination demonstrate the greatest correlation with deer and elk forage production. The equations thus derived will hopefully form a basis for the synthesis of a predictive simulation technique.

Ideally, the equations involving inventory-prediction variables that may be directly affected by vegetation management re-direction can be coupled with timber simulation models, such as those described by Myers (1971, 1973), to provide the technique whereby it will be possible to predict deer and elk forage production in Arizona mixed conifer forests. Essentially, a proposed vegetation management re-direction will be evaluated in terms of how the treatment may alter forest parameters as described by the timber simulation models. Then, if the forest descriptors in the timber simulation models are correlated with deer and elk forage production levels, as is hoped can be developed, it may be possible to simulate the change in deer and elk forage production following the vegetation management re-direction. Conceptually, this is the general approach that is being followed in the current exploratory study.

Validation of the simulation technique may be achieved by comparison of predicted and actual deer and elk forage production for sites on the South Fork of Thomas Creek experimental watershed where pre- and post-vegetation management re-direction inventory-prediction variables are known. In addition, on sites representing a variety of successional stages, pellet group data and vegetation composition will be evaluated, if possible, so that decision-making statements can be made relating to expected composition and persistence of forage considered to be benefical to deer and elk population.

LITERATURE CITED

Anderson, R.C., O.L. Loucks, and A.M. Swain. 1969. Herbaceous response to canopy cover, light intensity, and throughfall precipitation in coniferous forests. Ecology 50: 255-263.

Basile, Joseph V., and Chester E. Jensen. 1971. Grazing potential of lodgepole pine clearcuts in Montana. USDA Forest Serv. Res. Pap. INT-98, 11 p.

Clary, Warren P., Peter F. Ffolliott, and Donald A. Jameson. 1968. Relationship of different forest floor layers to herbage production. USDA Forest Serv. Res. Note RM-123, 3 p.

Ffolliott, Peter F., and Warren P. Clary. 1972. A selected and annotated bibliography of understory-overstory vegetation relationships. Ariz. Agr. Exp. Sta. Tech. Bull. 198. 33 p.

Ffolliott, Peter F. and Warren P. Clary. 1974. Predicting herbage production from forest growth in Arizona ponderosa pine. Progressive Agr. Ariz. 26(3): 3-5.

Giles, Robert H., and Nathan Snyder. 1970. Simulation techniques in wildlife habitat management. In: Modelling and Systems Analysis in Range Science. Donald A. Jameson (ed.) Range Science Dept., Science Series No. 5, Colorado State University. pp. 23-49.

Myers, Clifford A. 1971. Field and computer procedures for managed-stand yield tables. USDA Forest Serv. Res. Pap. RM-79, 29 p.

Myers, Clifford A. 1973. Simulating changes in even-aged timber stands. USDA Forest Serv. Res. Pap. RM-109 47 p.